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**Research Article**

# MG-MMG Care System for Muscle Rehabilitation Therapies in Upper Limb using Video Game

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**Abstract:** This study presents the design and development of a hardware/software to assist an arm rehabilitation therapy. Electromyography (EMG) and Mechanomyography (MMG) were used to calibrate the muscle activity according to the movements required by the therapist. The system has a video game with different difficulty levels, that generates the patients progress report in realtime to the medical personal with possibility to changing some parameters during the therapy.

**Keywords:** EMG, MMG, muscle activity, rehabilitation, therapy

## INTRODUCTION

The muscular rehabilitation is mainly applied to people that responds to diseases and problems that are permanent or transitory disability. The challenge for the medical staff is to develop a complete rehabilitation program designed specifically for each patient depending on their injury, disorder or illness (Sánchez Blanco, 2006; Ciro *et al*., 2007; Izquierdo, 2008).

The process of the muscle rehabilitation of the upper limb is performed with various exercise sequences involving the different muscles of the arms, depending on the range of the movements that allows the injury. When these muscles are exercised in therapy, the body produces electric arm potentials that are captured through Electromyography (EMG) (Silverthorn, 2008; Hall and Guyton, 2011).

The behavior of the muscles in the body can be analyzed in the captured of the movement performed by contracting and expanding (EMG), generating a mechanical response (MMG) that can be calculated or measured through devices such as accelerometers, gyroscopes and magnetometers (Dovat *et al*., 2008; Sivan *et al*., 2014; Oblak *et al*., 2009).

The use of devices that acquire these two signals and performed the analysis of their power content, helps in identifying the muscles involved in each movement assigned by the therapist (Cifuentes-Zapien *et al*., 2011; Lambercy *et al*., 2007).

Currently, the interdisciplinary of medical personnel and video game developers has been successfully carried out for the development of various systems studies that facilitate the capture of the exercise developed in a therapy session. Finally, the worldwide trend to create systems that can be used and monitored from home or office, avoiding large displacements has been a challenge for engineers and physicians (Lohse *et al*., 2014; Horne-Moyer *et al*., 2014).

The following article clearly presents the development and implementation of a medical assistance system for the remote rehabilitation of upper limbs used in Colombia.

## METHODOLOGY

The methodology used to develop the system to assist the medical staff during the implementation of therapies consists of two large software/hardware blocks: Biometric signal capture and processing (EMG and MMG) and graphical interface (video game) (Fig. 1).

In the following block diagram, the different stages that are needed for the construction of the system are observed. The power stage is in charge of providing the different power requirements of the device; The biometric capture and processing stage are responsible of obtaining the data of the muscles by means of the EMG and MMG, the analysis and communication box performs the device connection and microcontroller configuration and finally the GUI box takes care of the video game and the visualization of the database.

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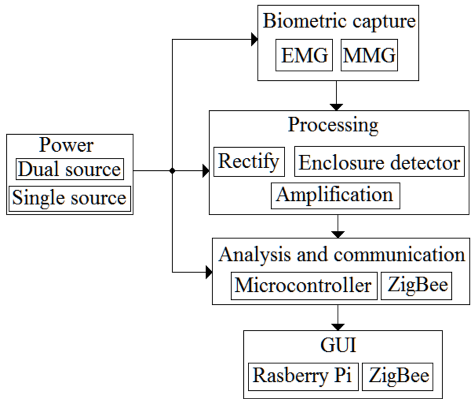



Fig. 1: General system block diagram

**Capture and processing of biometric signals (EMG y MMG):** The design of the electronic device for the capture of the biometric signals was developed with accelerometer, magnetometer and gyroscope sensors, were implemented through the use of a nine-axis Inertial Momentum (IMU) card. Following this, the Texas Instruments® TM4C123GH6PM microcontroller was chosen and the SBC used is the Raspberry Pi 2 model B. The communication protocols such as the I2C that allows the implementation of several devices on the same data bus, the GY-85 card is chosen, as well as the choice of Digi International inc® ZigBee wireless communication protocol through the asynchronous serial protocol (Sivan *et al*., 2014; Oblak *et al*., 2009).

The capture of biometric signals is performed by means of two techniques: electromyography (EMG) and mechanomyography (MMG). The first technique measures the potentials created in the muscle during a certain action. On the other hand, the mechanomyography registers the vibration that is generated when producing the movement in the muscle.

The capture by electromyography was designed to acquire the electrical signal of the palmar long and posterior flexor muscles. The reading electrodes are located for both muscles as follows: the red electrode in the middle of the muscle and the blue electrode at one end of the muscle, in this case always located at the lower end. The reference electrode or black electrode is the same for both cases and should be located in a preferably bony area, from there, which was located near the elbow.

The electronic circuit design of the EMG has: an amplification block of instrumentation, which amplifies the signals obtaining an optimal voltage range for the microcontroller; A voltage rectifier to limit the signal of the muscles to the threshold designated by the specialist physician during therapy; An inverter envelope detector circuit, so as not to alter the gain of the signal and finally a unit gain inverter block, to obtain the output signal of the biometric capture to be brought to the microcontroller (Fig. 2).

The capture of mechanomyography is obtained through the location of the IMU sensors where the greatest variation of the vertical-horizontal position of

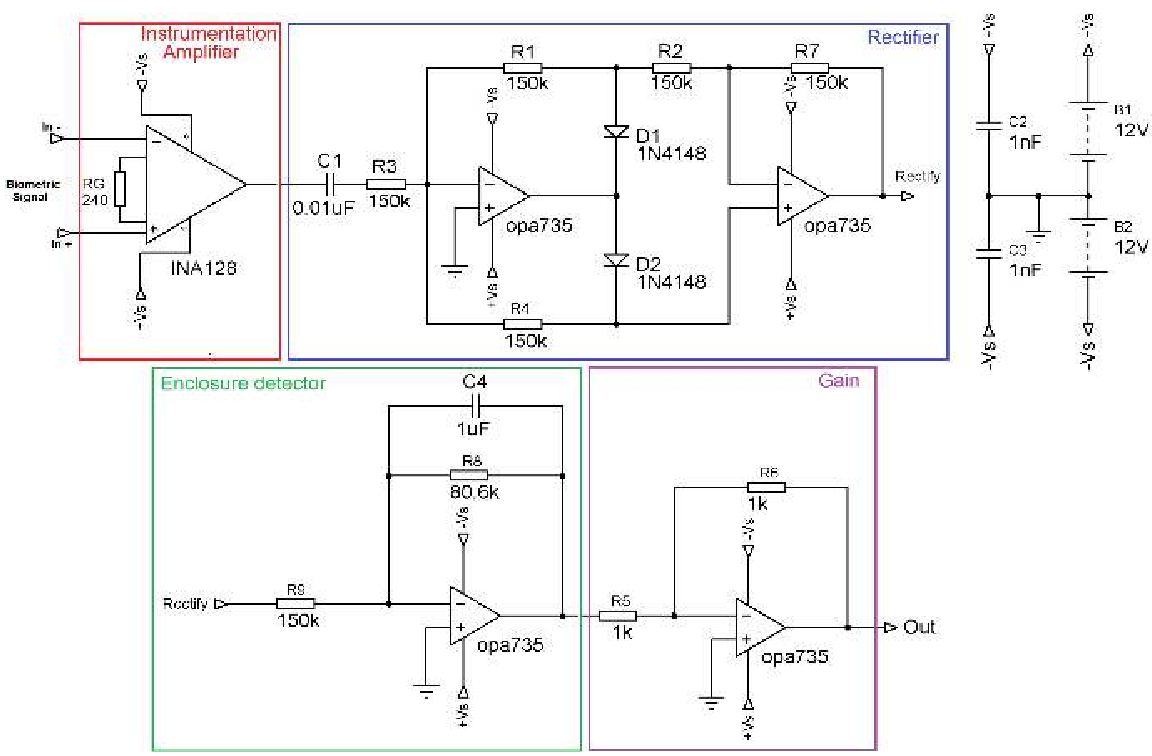



Fig. 2: Circuit for biometric capture of EMG

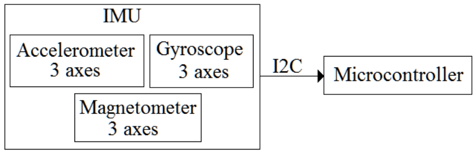



Fig. 3: Block diagram of IMU for biometric capture using MMG

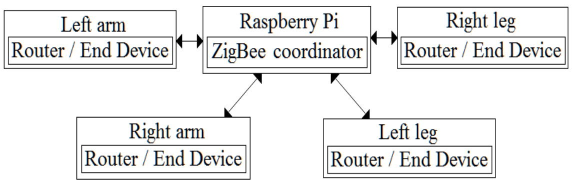



Fig. 4: Star topology for wireless communication

the subject is presented when the arm is moved and the signal obtained by these is analyzed by the microcontroller (Fig. 3).

Once the microcontroller acquires the signals provided by the IMU sensors during the execution of a movement, a digital analogue conversion (A/D) of the signals delivered by the electric potential capture cards is performed. Then, the data is normalized for each patient and thus ensure a custom working range for each patient during each therapy session.

Next, the signal delivered by the electric potential capture cards was studied to be able to analyze the shape of the signal depending on the rehabilitation movements performed. The response of IMUs, considering the position of the sensors, helps us to define the response values in which each movement is found during therapy.

The Raspberry Pi makes the connection to the devices verifying which is connected and then performs the calibration of each of them, then each device will send a signal captured and interpreted by the coordinator and represented in the GUI. The communication between the Raspberry Pi and the other devices uses star topology, because the coordinator communicates individually with each of the devices, without considering any hierarchy (Fig. 4).

**Graphic interface of the user GUI:** The Graphical User Interface (GUI) was performed on the Raspberry Pi. The programming language used for the development of the video game was Python v3.0, using the Python module Pi3D, designed to allow the use of 3D capabilities of the Raspberry Pi. The video game was developed under the creative commons environment, with the philosophy that the video game was modulable and easy to edit the therapies in conjunction with medical personnel.

Due to the main objective of the project, to enliven patient therapy sessions, the developed video game is a first person exploration, where the protagonist is located inside a base on an unknown planet, as the user performs the Rehabilitation exercises execute actions within the video game, which are edited by medical personnel to address a whole therapy in one or several levels of the video game (Fig. 5).

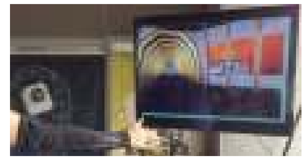


Fig. 5: EMG-MMG arm device and first-person video game environment

## RESULTS

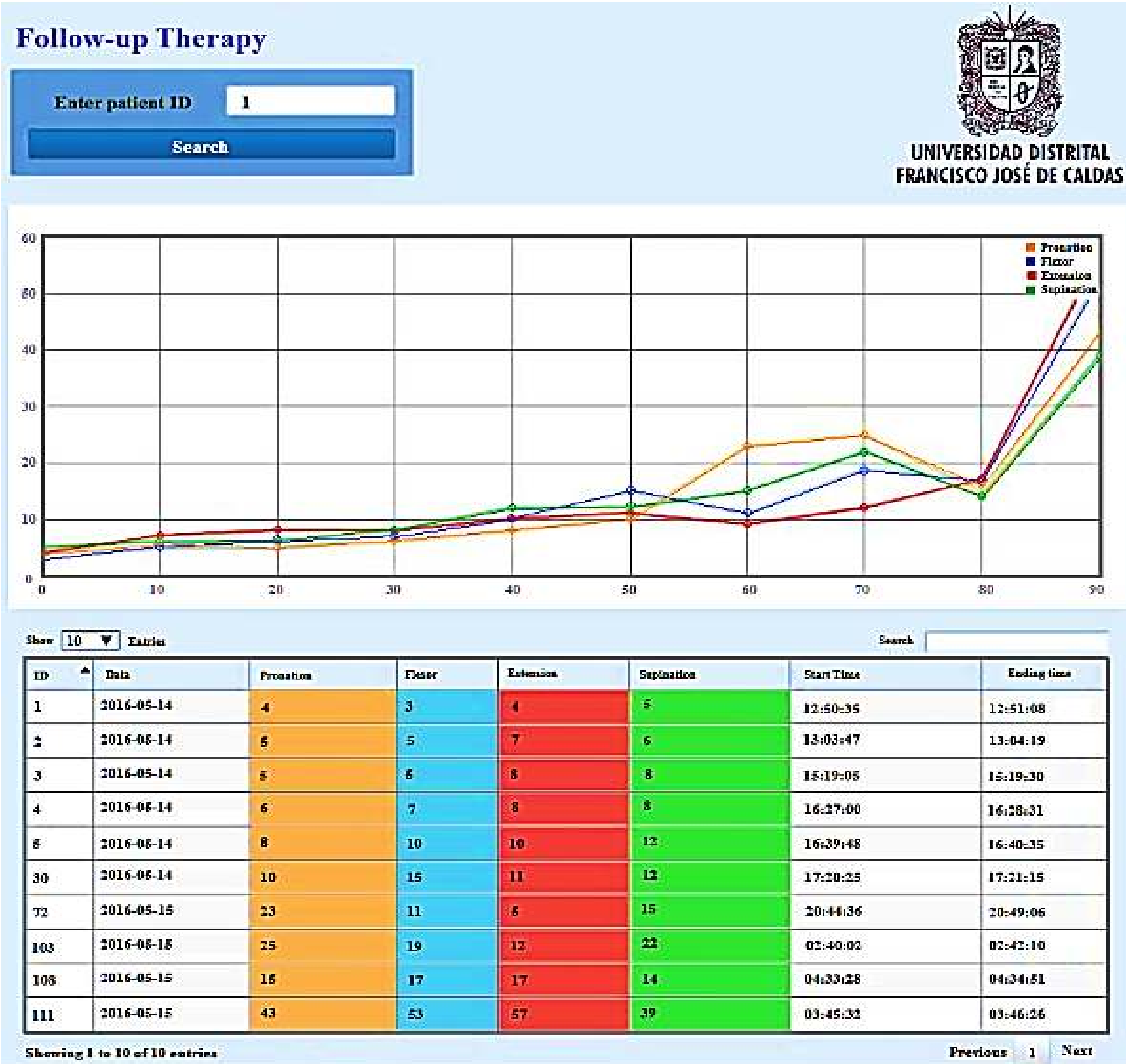
The results obtained during the execution of the system are the assistance in the remote monitoring of the therapies in real time, as well as the storage of therapy in a database, recording the following data: number of repetitions of each movement performed, the type of movement performed, the date and time of the therapy and the potentials of the muscles, for each session performed of the patient. A graphical report of a patient during a therapy session with all the data can be plot, stored and analyzed by an expert (Fig. 6).

Electromyography (EMG) provides a difference in signal strength between a healthy person and a person with muscle problems, which provides information on muscle activation. There were some changes in the voltage threshold during each movement in the flexor and extensor muscles: obtaining a power increase when the muscle group was stressed, otherwise, when the muscle group was relaxed the power of the signal decreased considerably (Fig. 7), where the red signal corresponds to the flexor muscles and the blue signal corresponds to the extensor muscles.

After testing in 10 people (5 healthy and 5 pathological), it was observed that people enjoyed the therapy session and that they did not suffer any muscular problems in the different levels of sensitivity provided in the video game. On the other hand, it is perceived a greater time in reaching the point of muscle fatigue, which allows an adequate response of the levels of difficulty of the video game.

## DISCUSSION

The signal from the long palmar and flexor ulnar muscles provided the best response compared to the other muscles of the arm. In addition, having the electrodes on the front and back of the forearm respond to the same reference, so it was located near the elbow. It was evidenced that the muscles present an offset depending on the fatigue of the same ones. Therefore, the ADC is set to calculate the offset level and from the resulting value the reference can be taken for the respective calculations.




| ID | Data | Pronation | Flexor | Extension | Supination | Start Time | Ending time |
|---|---|---|---|---|---|---|---|
| 1 | 2016-05-14 | 4 | 3 | 4 | 5 | 12:50:35 | 12:51:08 |
| 2 | 2016-05-14 | 5 | 5 | 7 | 6 | 13:03:47 | 13:04:19 |
| 3 | 2016-05-14 | 5 | 6 | 8 | 8 | 15:19:05 | 15:19:30 |
| 4 | 2016-05-14 | 6 | 7 | 8 | 8 | 16:27:00 | 16:28:31 |
| 5 | 2016-05-14 | 8 | 10 | 10 | 12 | 16:39:48 | 16:40:35 |
| 30 | 2016-05-14 | 10 | 15 | 11 | 12 | 17:20:25 | 17:21:15 |
| 72 | 2016-05-15 | 23 | 11 | 8 | 15 | 20:44:36 | 20:49:06 |
| 103 | 2016-05-15 | 25 | 19 | 12 | 22 | 02:40:02 | 02:42:10 |
| 108 | 2016-05-15 | 15 | 17 | 17 | 14 | 04:33:28 | 04:34:51 |
| 111 | 2016-05-15 | 43 | 53 | 57 | 39 | 03:45:32 | 03:46:26 |

Fig. 6: Report generated in real time during the execution of a therapy. The columns and colored lines represent different executed movements

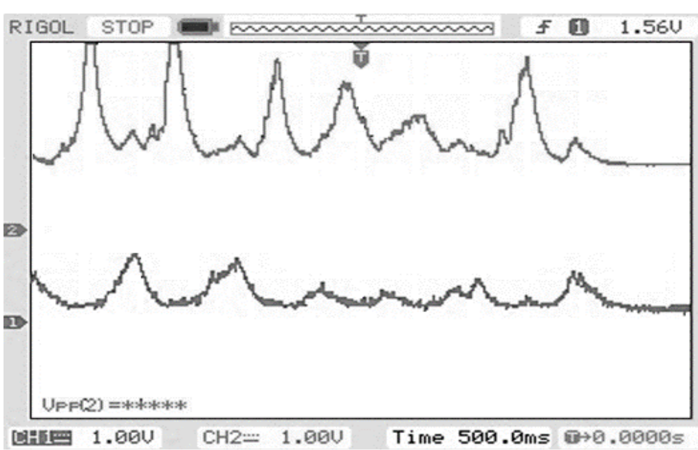



Fig. 7: EMG signal recorded during therapy

People with muscular pathology in their upper limbs showed good response to the most demanding sensitivity levels. The choice of the correct level and time of therapy has to be evaluated by medical personnel, since they have less muscle fatigue compared to healthy people.

The friendly and modular interface makes it an excellent choice for use in people of different age ranges. The future work of this research requires adaptation of the device to other muscles of the body (lower limbs), tests with a greater number of people and development of mobile applications.

## CONCLUSION

The system was evaluated positively by a physician and a physiotherapist, because sensitivity levels require the correct exercise and the option of providing a placid session of therapy, with remote monitoring in real time. The development and implementation of systems that facilitate the monitoring of a therapy remains a challenge for engineering and medicine. The device developed in this research, helps considerably to reduce the problems of displacement of people with muscular pathologies, as well as, the agglomeration of people in health care centers.

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**Conflict of interest:** The authors certify that there are no financial/relevant interest that may have influenced the development of the manuscript.

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